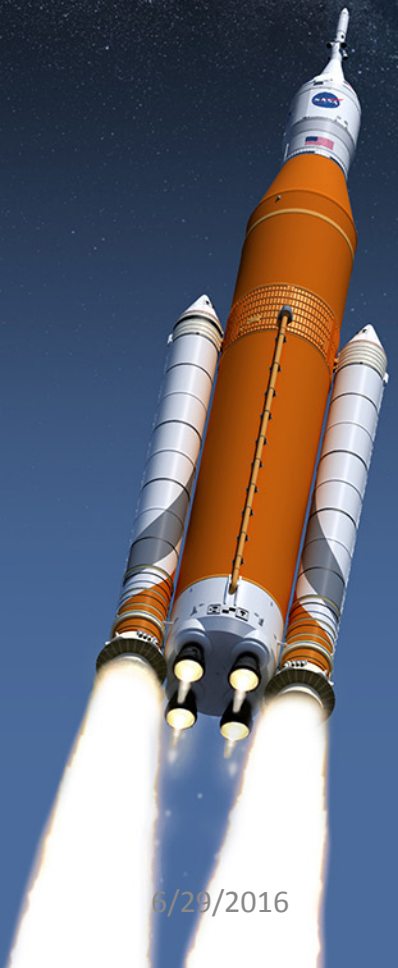
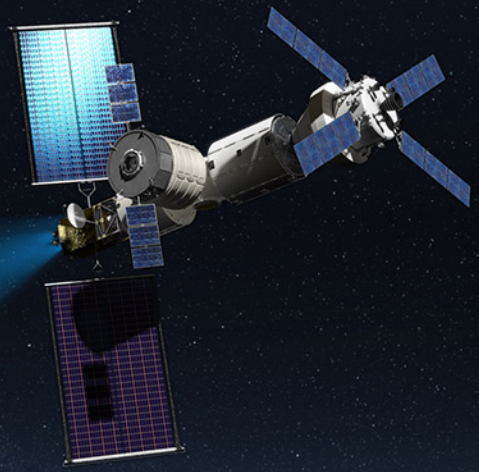
National Aeronautics and Space Administration





Planning for Crew Exercise for Exploration Mission Scenarios

JSC High School Aerospace Scholars
June 30, 2016
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Exploration Exercise Technology Development Manager

Content Summary

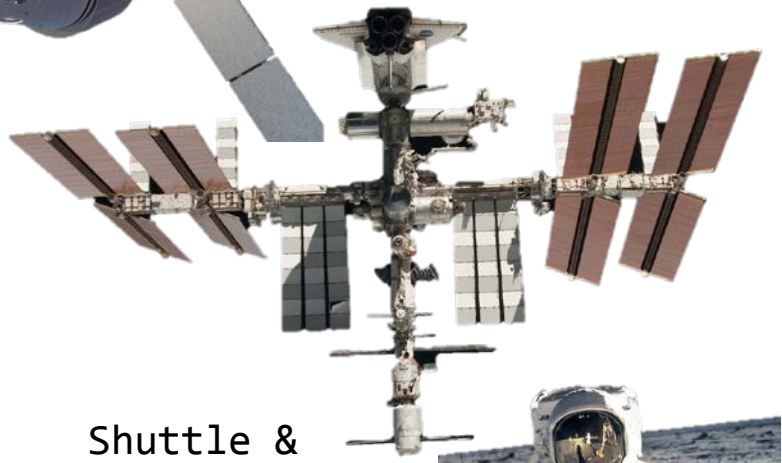
- Introduction
- Drivers for Defining the Hardware for the Exercise System
- Why Exercise?
- What type of equipment?
- Designing Vehicles to Support Exercise
- Exercise Operations Considerations
- Opportunities for Improving Integration of Exercise into Vehicles
- Conclusion

Introduction

Future: Beyond LEO, to Moon and Mars

Human Exploration continues into deep space

Orion MPCV



Shuttle & International Space Station

Apollo

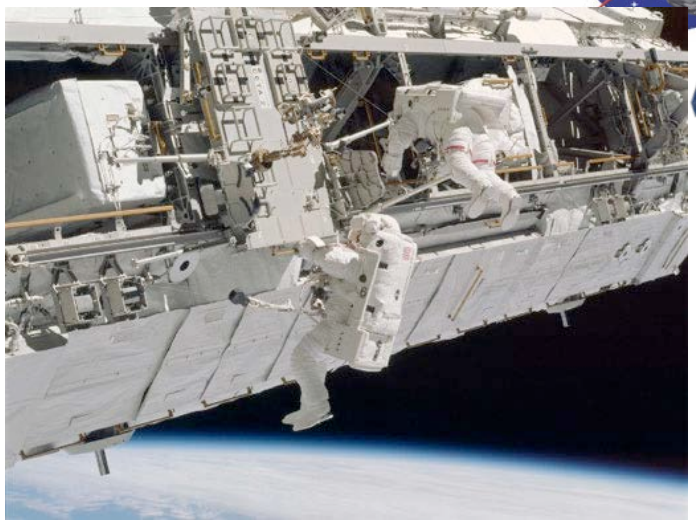
Gemini

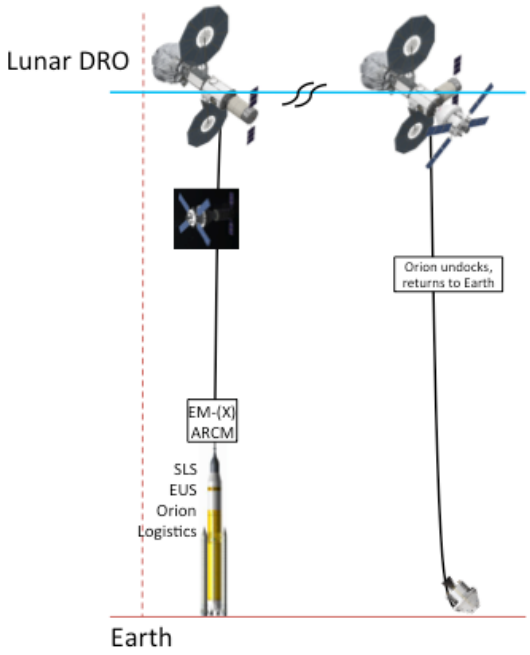
Space travel subjects the human body to environments that causes the body to change in many physiological areas. Exercise acts as a significant mitigation for many of these changes.

Defining Drivers for Exercise Systems

Reasons for need and types of exercise:

- General Crew Health:
  - Counteracts physiological deterioration
- Overall mission duration partially informs amount of deterioration/types of hardware:
  - Protection against bone loss/sensorimotor mitigation biggest reason
  - Large impact to robustness and engineering
- Mission tasks:
  - Extravehicular Activities (EVAs)
  - Planetary activities
  - Vehicle reentry and landing scenarios and degree of crew responsiveness needed
- Number of devices needed:
  - Number/location of vehicles involved and duration in each vehicle
  - Operational scheduling approach
  - Number of crew



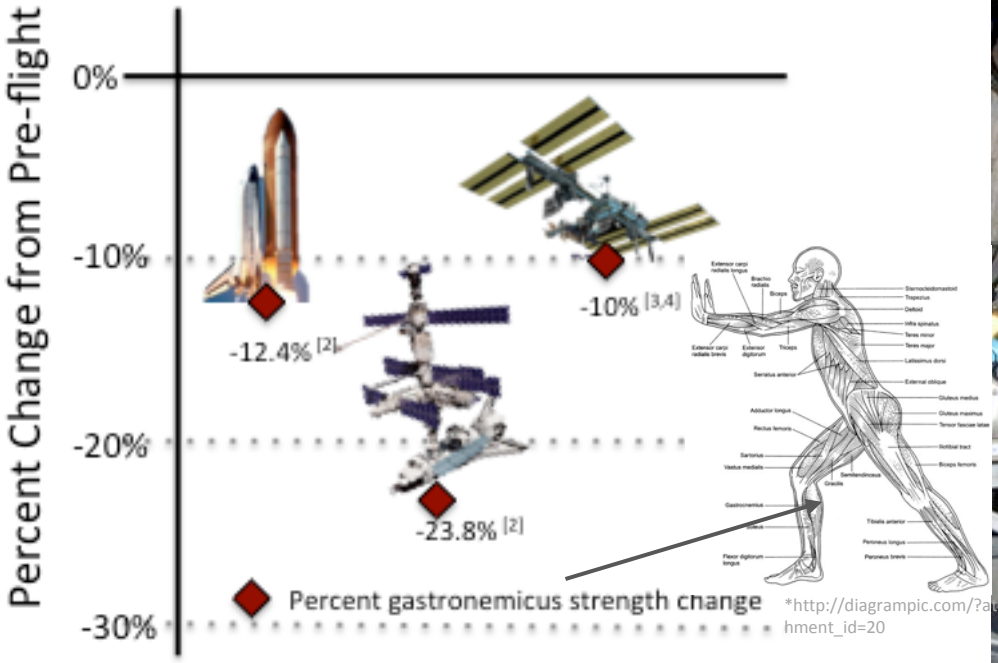


Why Exercise?

To Protect for Muscular Health

The prescribed exercise programs require robust, highly capable equipment that allows for high intensity, loads, movements, and frequent use.

Video: Mike Hopkins exercising on ARED



[2] LeBlanc, A., et al., *Muscle volume, MRI relaxation times (T2), and body composition after spaceflight.* J Appl Physiol, 2000. **89**(6): p. 2158-64.

[3] Gopalakrishnan, R., et al., *Muscle volume, strength, endurance, and exercise loads during 6-month missions in space.* Aviat Space Environ Med, 2010. **81**(2): p. 91-102.

[4] Trappe, S., et al., *Exercise in space: human skeletal muscle after 6 months aboard the International Space Station.* J Appl Physiol (1985), 2009. **106**(4): p. 1159-68.

Resistive exercise on ISS's ARED

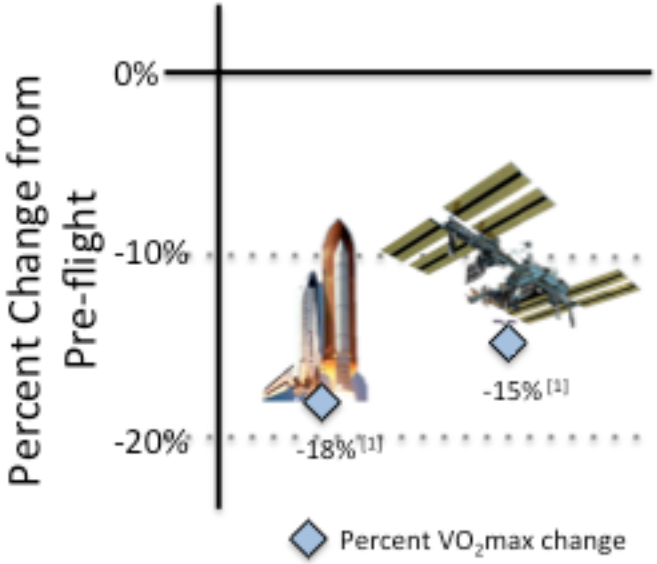
Why Exercise?

To Protect for Aerobic Health

Endurance type performance is impacted by changes in oxygen utilization measured via VO_{2max}.

Endurance changes can impact the crews' abilities to perform EVAs or other strenuous activities.

[Video: Karen Nyberg running in Space]



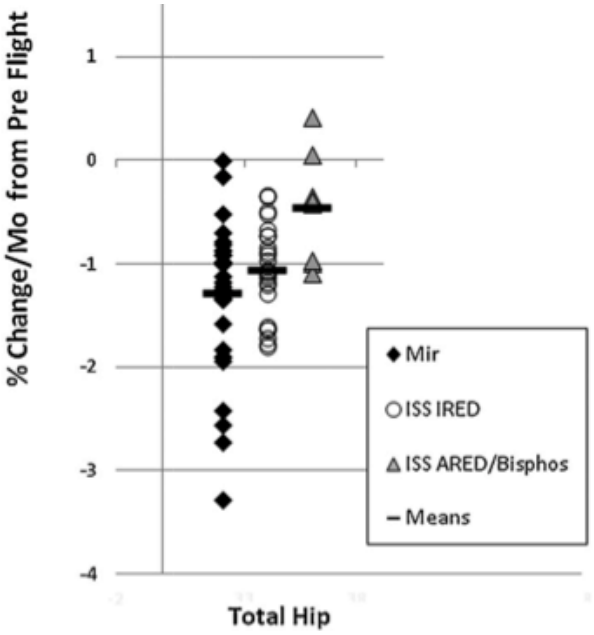
[1] Moore, Alan D., et. al., *Cardiovascular exercise in the U.S. space program: Past, present and future*. Acta Astronautica (2010). **66**: p. 974-988.

Treadmill exercise on ISS's T2

Why Exercise?

To Protect for Bone Health

- Bone resorption is promoted by gravitational unloading which under chronic conditions may elevate risks for fracture or early onset osteoporosis.
- 5% bone loss for 6 mo. ISS crew was reduced by half with upgrade from iRED to ARED which allowed for higher resistive loads



Unlike muscle and aerobic capacity concerns, effects are considerably more limited during < 3 week missions.

Orwolll, Eric S., et. al., *Skeletal Health in Long-Duration Astronauts: Nature, Assessment, and Management Recommendations from the NASA Bone Summit*. Journal of Bone and Mineral Research (June 2013). **Vol 28, No. 6**: pp.1243-1255.

Why exercise?

- Exercise can bring additional benefits:
  - Can partially improve the vestibular/sensorimotor responses,
  - Can improve immune system response,
  - Can improves behavioral health
  - In case of injury, can support rehabilitation
  - Can reduce risk for renal stone formation
  - Can reduce risk for cardiac rhythm events
  - Can reduce risk of space adaptation back pain

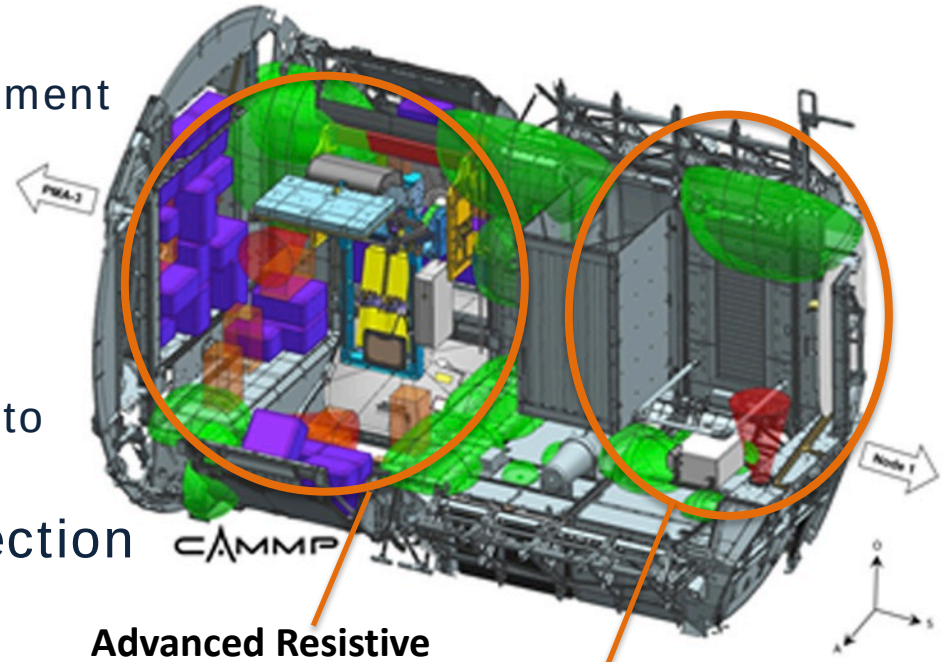
What type of equipment?

Performance Capabilities:

- Physiological-driven parameters
  - *Resistive exercise loading:* 0-600 lb., support rapid movements, various types of exercises, eccentric overloading, improved load profiles
  - *Aerobic exercise:* treadmill speeds up to 12+ mph with body weight loading, cycling resistance capabilities greater than 400W, or rowing up to 40-60 reps per minute.
  - *Bone loss mitigation:* higher resistive loads and high ground reaction forces from treadmill and/or resistive exercises
- Monitoring for insight into crew and hardware health; examples as follows:
  - heart rate,
  - loading,
  - power/current,
  - thermal, etc.
- Mounting structure:
  - Vibration, isolation & stabilization needed to protect the vehicle and possibly for microgravity research,
  - Provide sufficient stability for exercise activities
  - Robustly built so as not to bend or buckle during repeated usage
- Control systems/Interfaces

Designing Vehicles to Support Exercise

- Operational volume
  - Crew size-driven exercise volume
  - Hardware system volume
  - Crew and hardware dynamic movement
- Location within vehicle
  - Translation paths
  - Adjacent activities
  - Noise
  - Exercise System interfaces access to vehicle systems
- Vehicle structural loading protection
- Power/Thermal management
- Metabolic Management
  - Cooling,
  - O_2 consumption,
  - CO_2 removal,
  - Humidity management
- Data transmission



Model of ISS Node 3 with ARED and T2 exercise hardware

Exercise Operations Considerations

Number of crew and scheduling

One exercise operational volume would probably not support more than 4 crew, so additional volume would be needed for more crews. Charts below show exercise time for 4 crew would require ~10 hrs/day.

With 4 crew **habitable volume would not be available** for other activities.

Exercise Timelining Assumptions

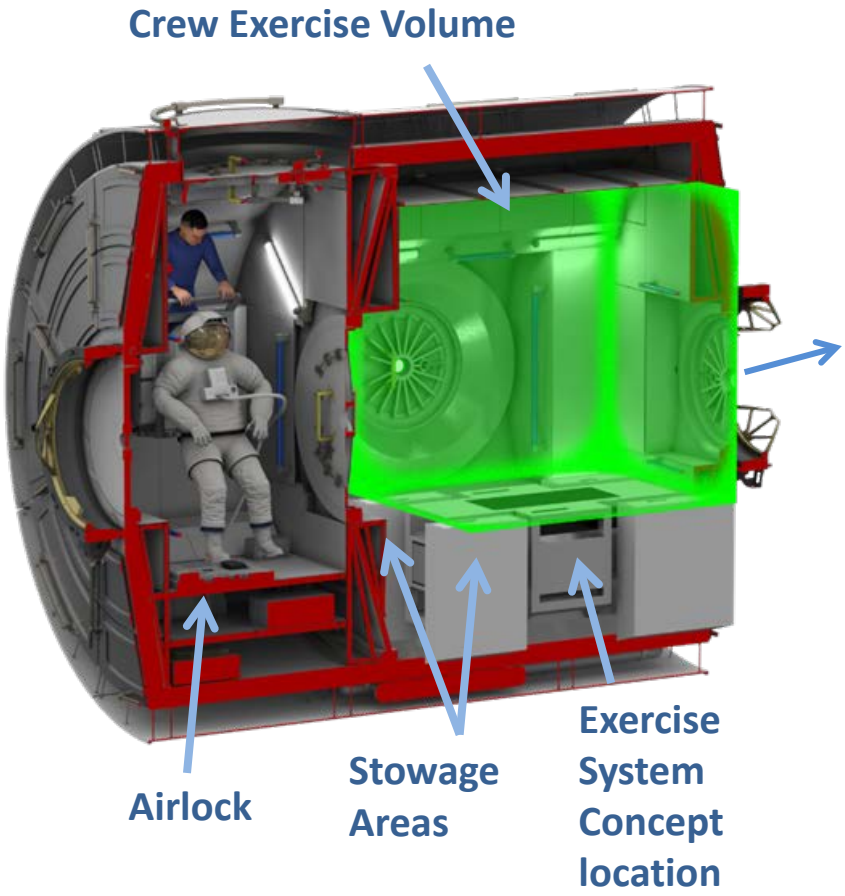
Activity	Assumed Duration (hrs)
Sleep	8.5
Post-sleep & Meal	1.5
Lunch (assumes 30 minutes overlap for all crew)	1
Pre-sleep & meal	2
Workday	11
Time after meals before exercising permissible	0.5
Assumes one exercise day off for each crew per week	
Assumes 1 hour aerobic exercise per crew for 6 of 7 days (includes 30 minutes for clothing changes, hardware setup, shutdown and cleanup time)	1
Assumes 1.5 hours resistive exercise per crew for 6 of 7 days (includes 30 minutes clothing changes, hardware setup, shutdown and cleanup time)	1.5

Exercise One-Week Scheduling Timeline example

Hour	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
8.5 hr	Sleep						
1.5 hr	Post-Sleep & meal						
.5 hr	Post-meal recovery						
1 hr	A1		A1	A1	A1	A1	A1
1.5 hrs	R2	R2		R2	R2	R2	R2
1 hr	A3	A3	A3		A3	A3	A3
1.5 hrs	R4	R4	R4	R4		R4	R4
1 hr	Lunch						
.5 hr	Post-Lunch Recovery						
1.5 hr	R1		R1	R1	R1	R1	R1
1 hr	A2	A2		A2	A2	A2	A2
1.5 hr	R3	R3	R3		R3	R3	R3
1 hr	A4	A4	A4	A4		A4	A4
2 hr	Pre-sleep						
Day off		Crew 1	Crew 2	Crew 3	Crew 4		

Opportunities for Improving Vehicle design for exercise

- Habitable volume is a limited resource
  - Optimizing crew volume needed
  - Optimizing exercise system volume needed
- Launch mass is costly
  - Optimizing exercise system mass contribution to vehicle including support hardware
- Systems integration
  - Identify the ideal power:mass:volume:performance ratios for future missions
  - Optimize structures and structural interfaces
  - Optimize data updates, on-orbit management, and downlink



Conceptual module with exercise area highlighted

Making better exercise systems

What will the next generation of exercise hardware do and look like?

Miniature Exercise Device concept

[Video: Intro Description]

[Video: Fernando's interview]

ROCKY MPCV concept

[Video: Exoskeleton] approach?

Or?....

What would you design?

Conclusion

- The need for exercise is critical in the spaceflight environment to protect crew health.
- Future deep space missions could be used as testing grounds for new exercise systems expected to be used for longer duration exploration missions.
- Advances in exercise systems for exploration can also benefit the commercial exercise market